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# (54) Liquid crystal colour display device

(57) A liquid crystal colour display device, e.g. for TV, comprises a pair of transparent substrates (1, 2) and a matrix of picture elements arranged in rows and columns. Each picture element is composed of a drive circuit (3), a first driving electrode (4) on one substrate (2), a second driving electrode (5) and a colour filter (8, 9, 10) of one of the primary colours on the other substrate (1) and a liquid crystal material (7) between the electrodes (4, 5), the colour filters on the substrate (1) being arranged in a mosaic or in strips. The drive circuit (3) may be e.g. a thin film transistor or a non-linear resistor.

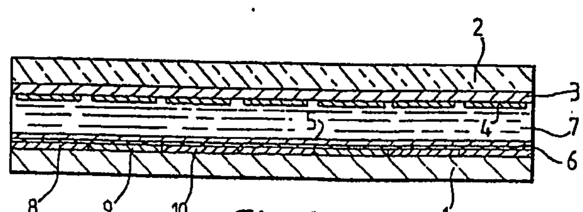


Fig.1.

GB 2 130 781 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

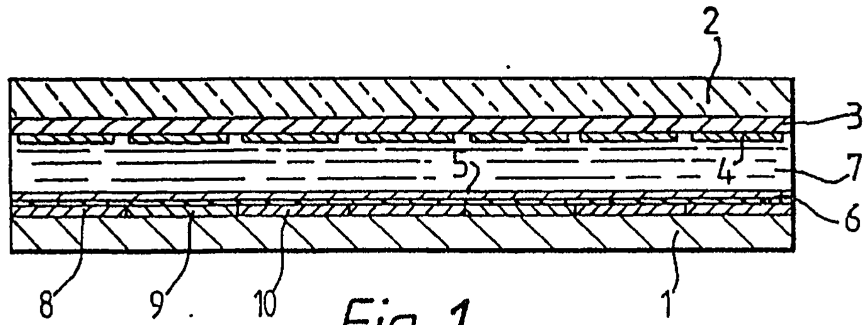



Fig.1.

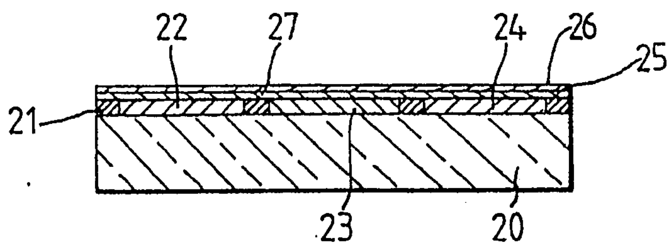



Fig.2.

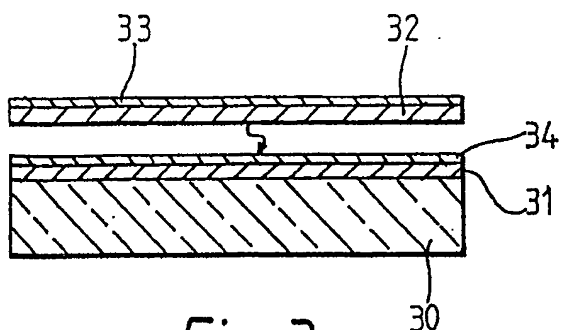



Fig.3.

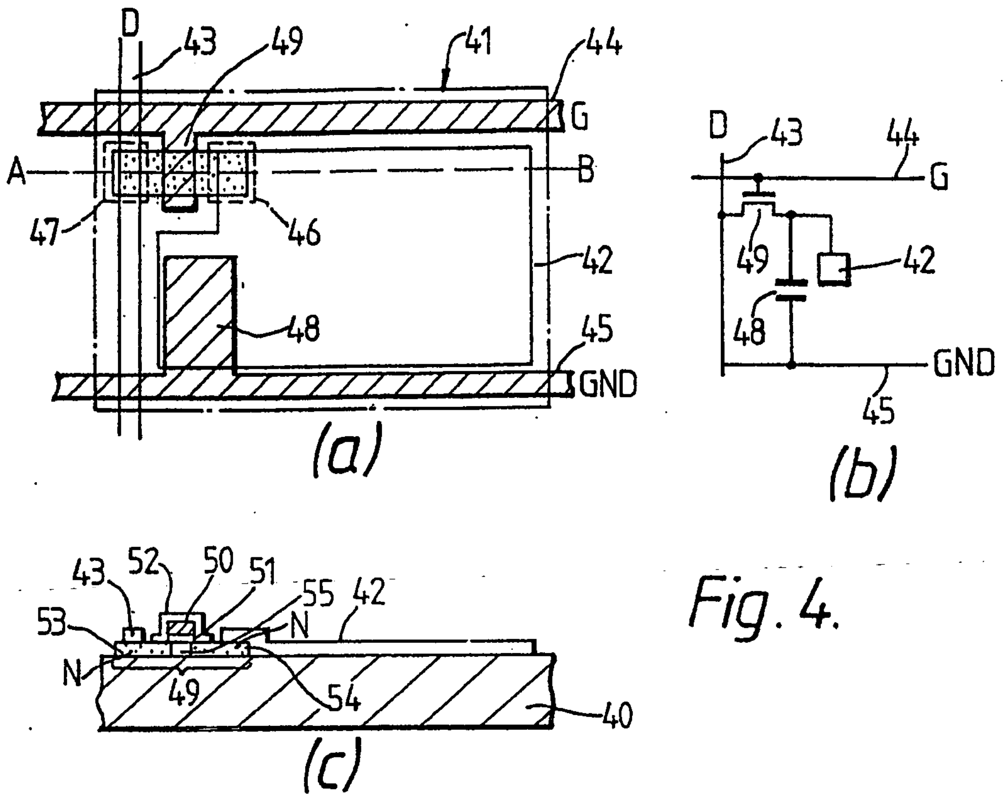



Fig. 4.

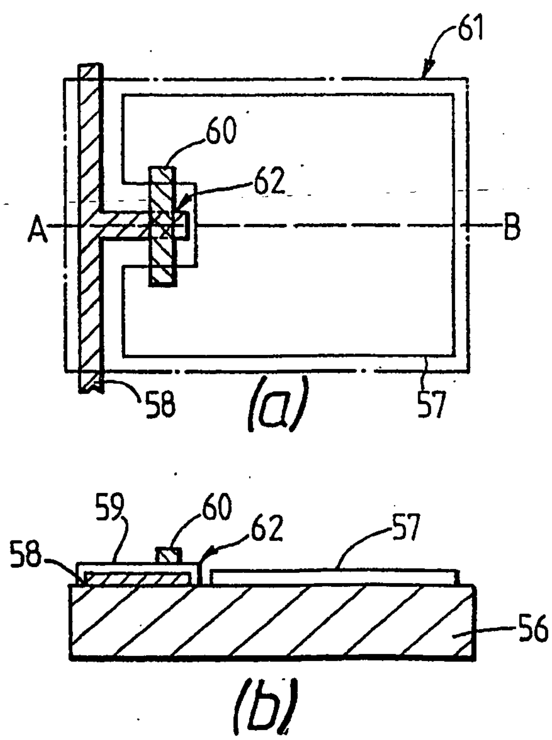



Fig.5.

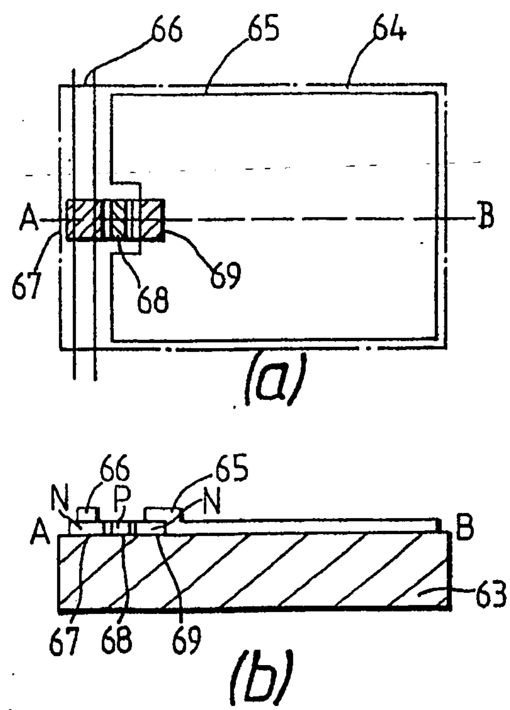



Fig.6.

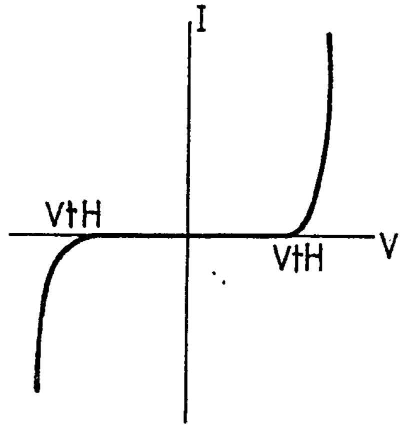



Fig. 7.

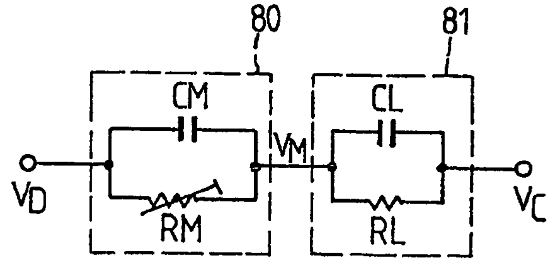
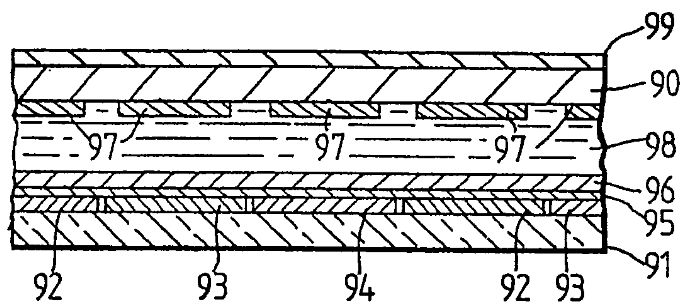
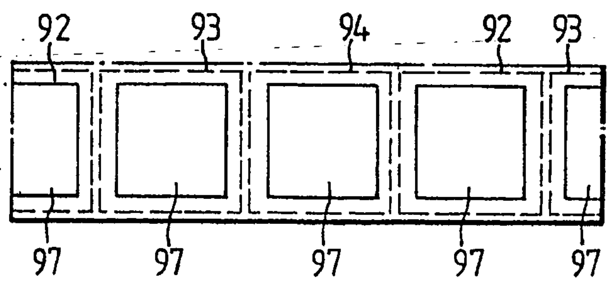



Fig. 8.

(a)




(b)




(c)

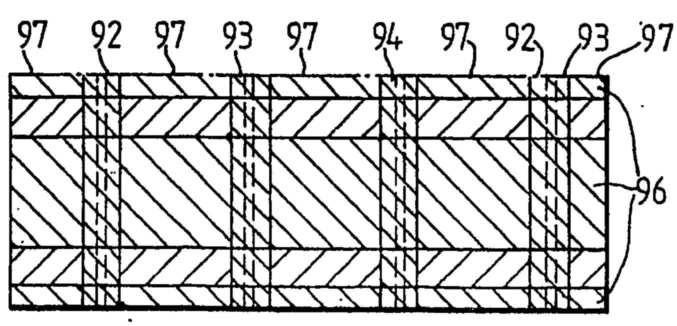



Fig. 9.

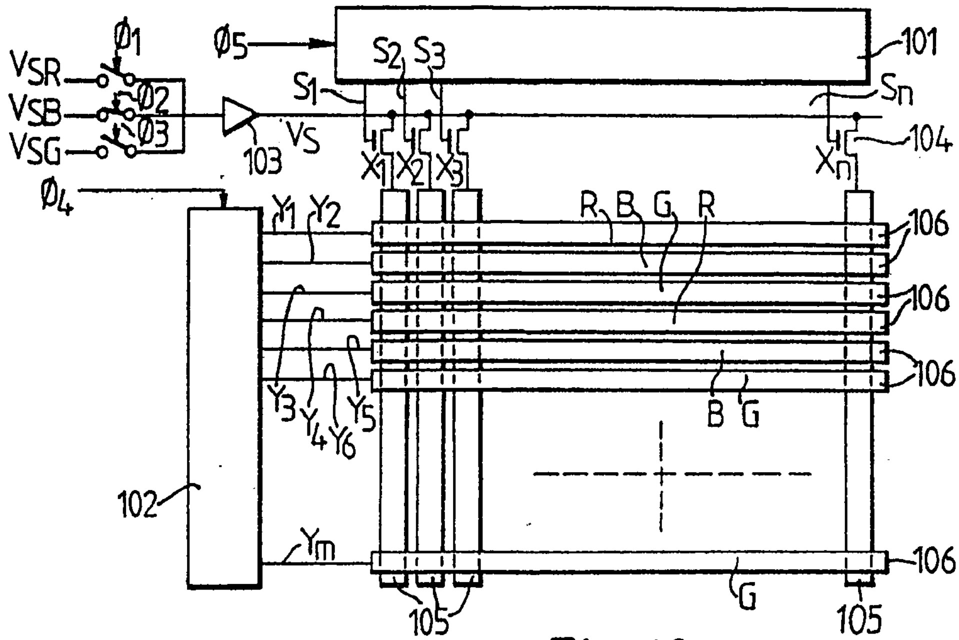
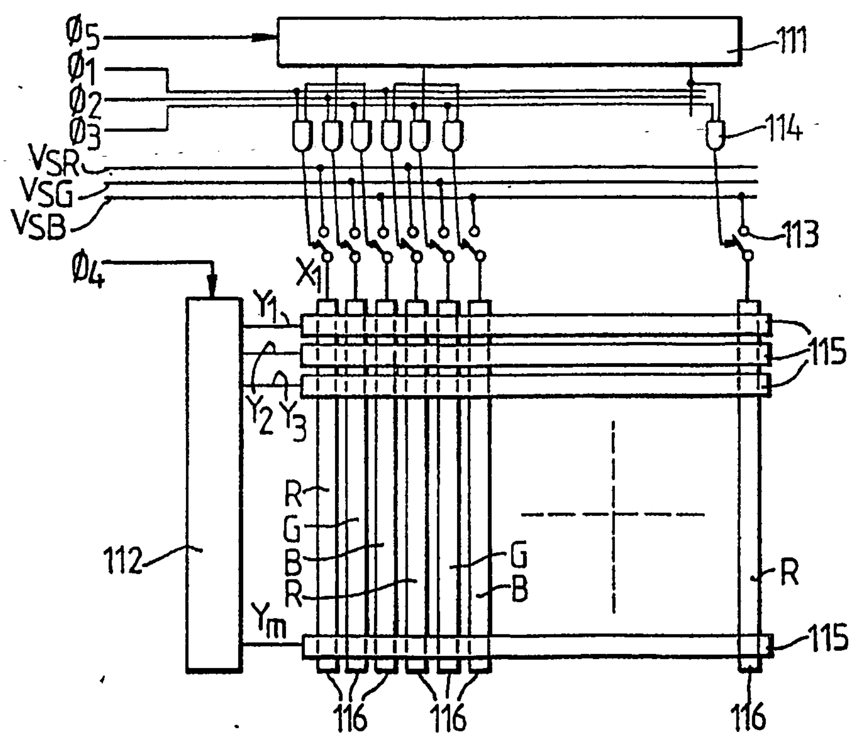

Ø1
Ø5
VSR
VSB
VSG
Ø2
Ø3
103
VS
S2 S3
S1
101
Sn
104
X1 X2 X3
Xn
Ø4
Y1 Y2
R B G R
106
Y3 Y4 Y6 Y5
B G
102
Ym
G
105

Fig. 10.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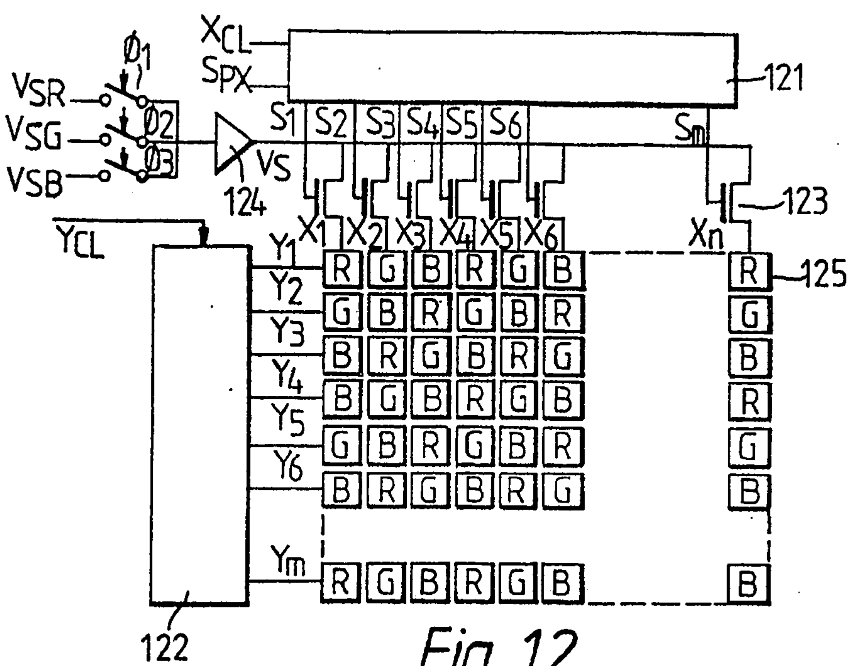
Ø1
Ø2
Ø3
111
114
VSR
VSG
VSB
113
Ø4
X1
Y1
115
Y2 Y3
R
G
B
R
G
B
112
Ym
116

Fig. 11.


XCL
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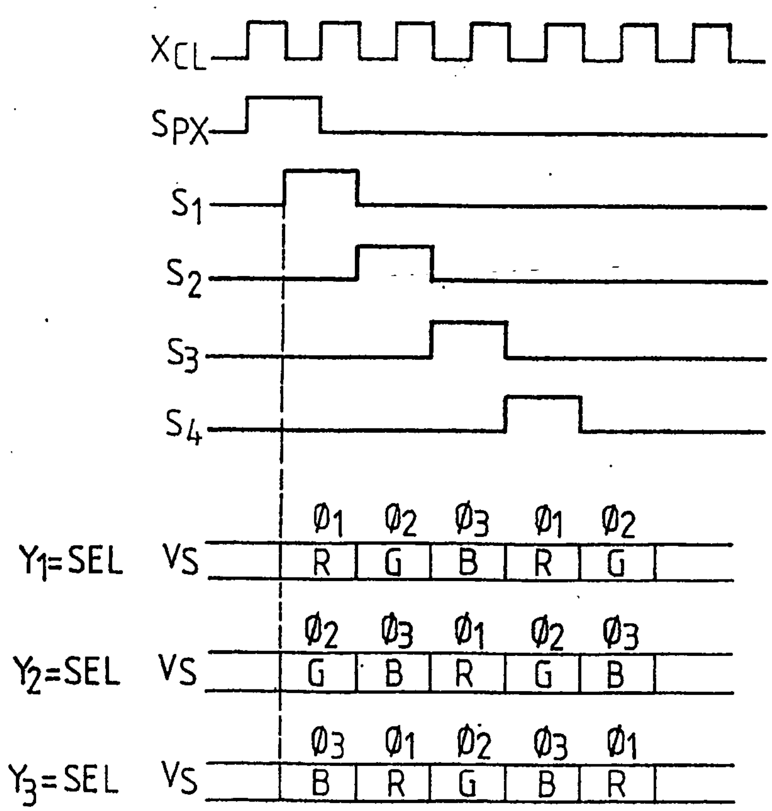
Ø2
Ø3
VSR
VSG
VSB
VS
124
121
S1 S2 S3 S4 S5 S6
Sm
123
X1 X2 X3 X4 X5 X6
Xn
YCL
Y1
Y2
Y3
Y4
Y5
Y6
Ym
R G B R G B
G B R G B R
B R G B R G
B G B R G B
G B R G B R
B R G B R G
R G B R G B
125
122

Fig. 12.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SPX
S1
S2
S3
S4
Y1=SEL VS
Ø1 Ø2 Ø3 Ø1 Ø2
R G B R G
Y2=SEL VS
Ø2 Ø3 Ø1 Ø2 Ø3
G B R G B
Y3=SEL VS
Ø3 Ø1 Ø2 Ø3 Ø1
B R G B R

Fig. 13.

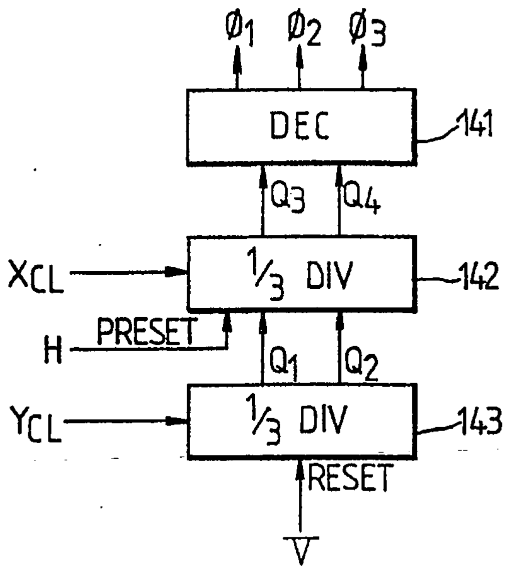

Ø1
Ø2
Ø3
DEC
141
Q3
Q4
XCL
1/3 DIV
142
PRESET
H
Q1
Q2
YCL
1/3 DIV
143
RESET

Fig. 14.

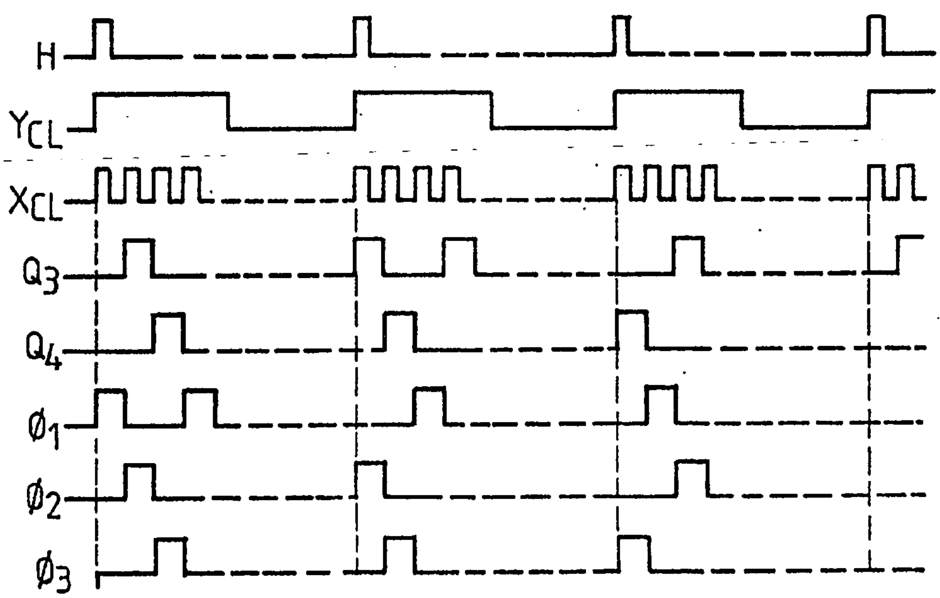

H
YCL
XCL
Q3
Q4
Ø1
Ø2
Ø3

Fig. 15.

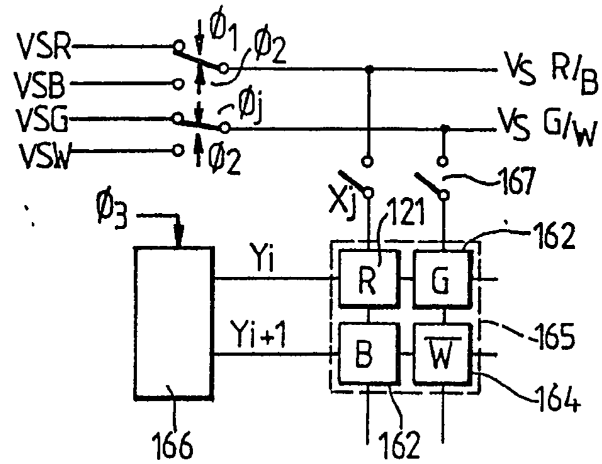

VSR
VSB
VSG
VSW
Ø1
Ø2
Øj
Ø2
Vs R/B
Vs G/W
Ø3
Xj
121
167
162
Yi
Yi+1
R
G
B
W
165
164
166
162

Fig. 16.

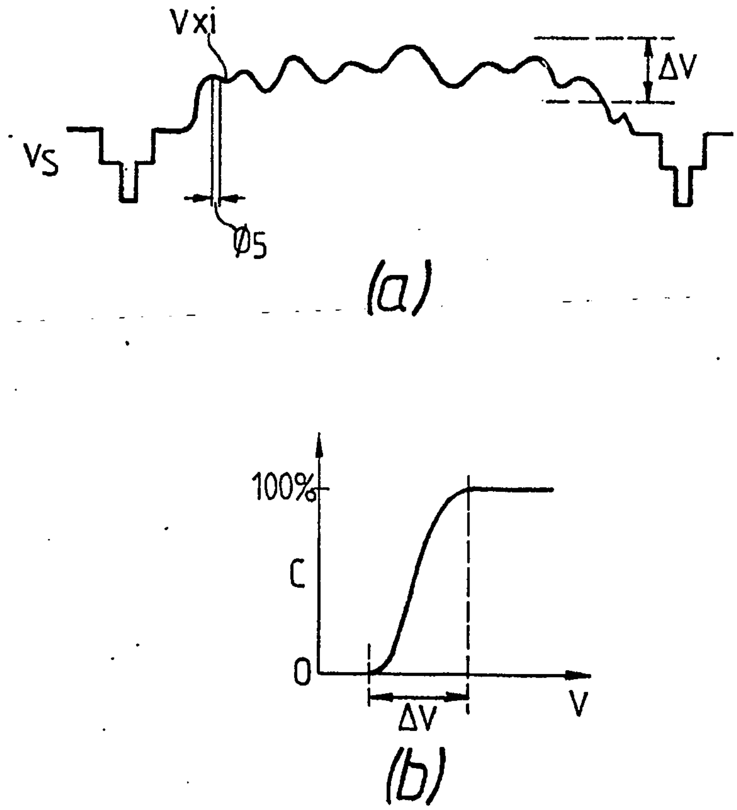
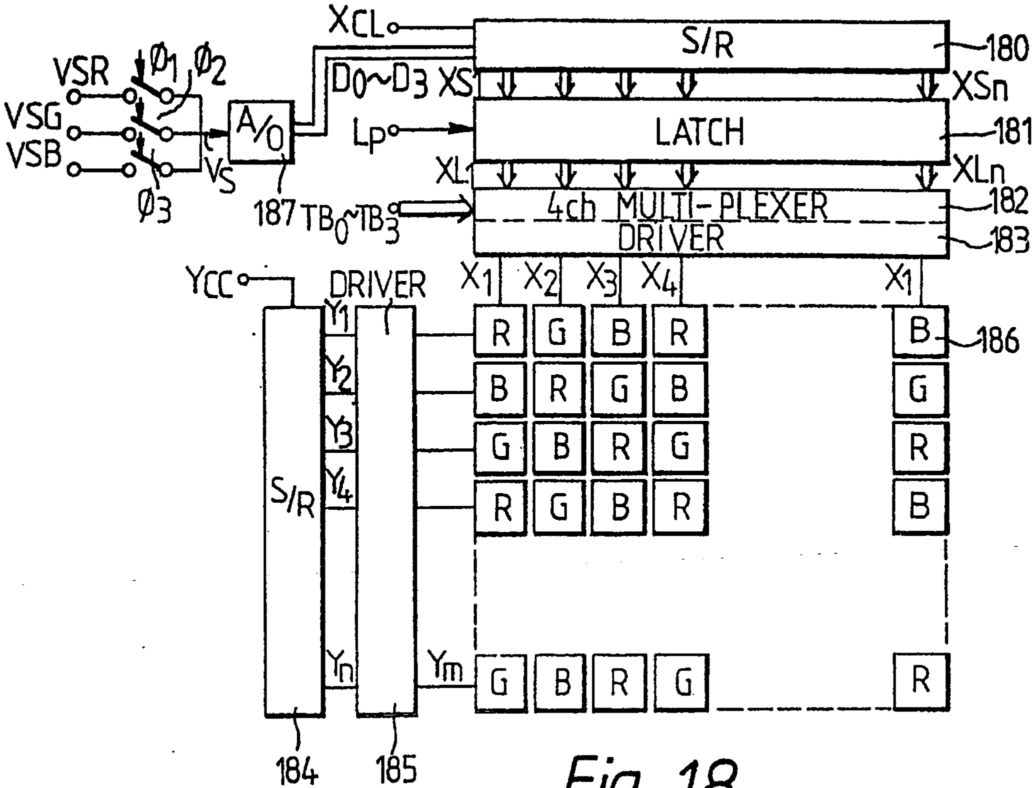

Vxi
ΔV
Vs
Ø5
(a)
100%
C
0
ΔV
V
(b)

Fig. 17.


XCL
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D0~D3
XS1
XSn
VSR
VSG
VSB
Ø1
Ø2
Ø3
A/D
VS
187
LATCH
181
Lp
XL1
XLn
TB0~TB3
4ch MULTI-PLEXER
182
DRIVER
183
YCC
DRIVER
X1
X2
X3
X4
Y1
Y2
Y3
Y4
Yn
Ym
S/R
186
184
185

Fig. 18.

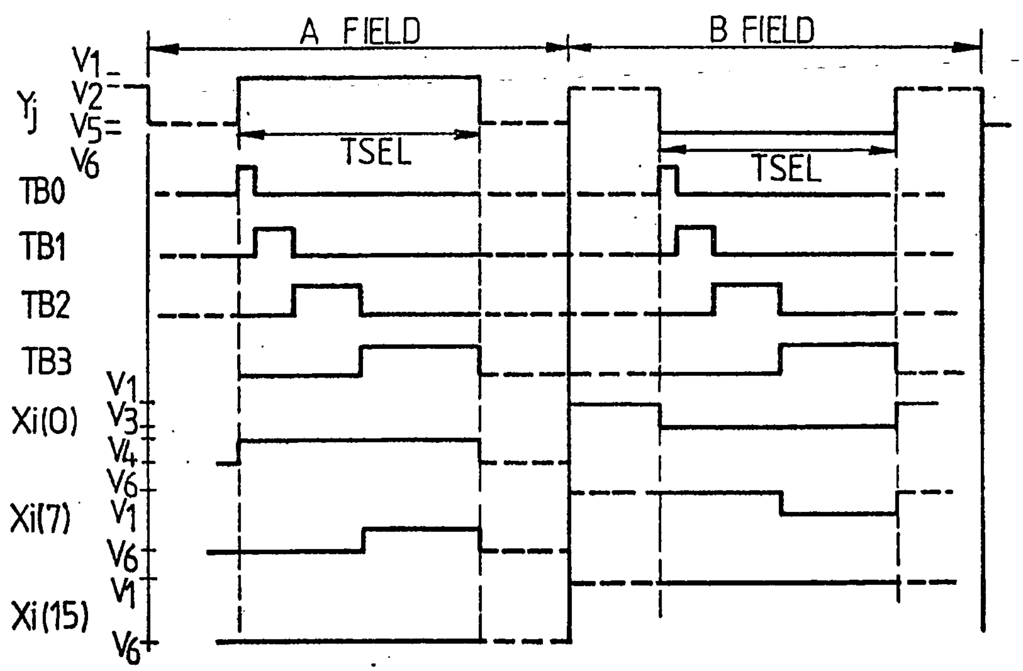
A FIELD
B FIELD
Yj
V1
V2
V5
V6
TSEL
TB0
TB1
TB2
TB3
Xi(0)
V3
V4
Xi(7)
Xi(15)

Fig. 19.

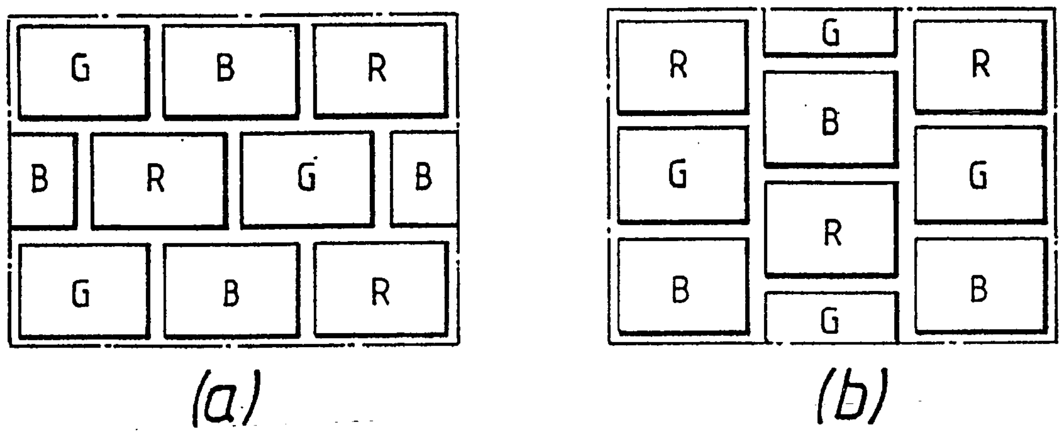


Fig. 20.

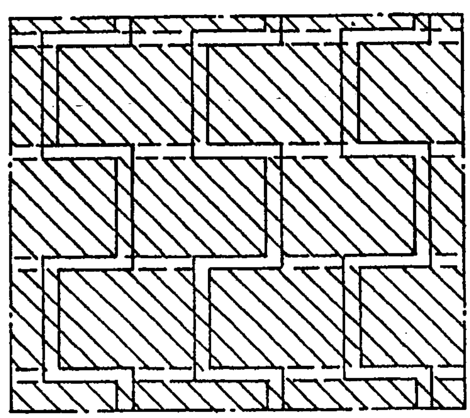

Fig. 21.

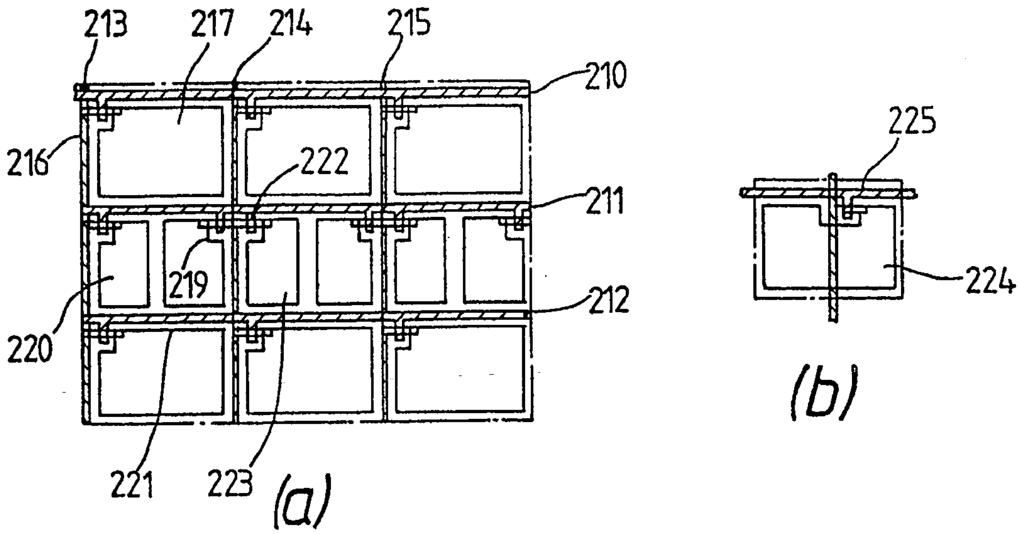
213
217
214
215
210
216
222
211
219
212
220
221
223
(a)
225
224
(b)

Fig. 22.

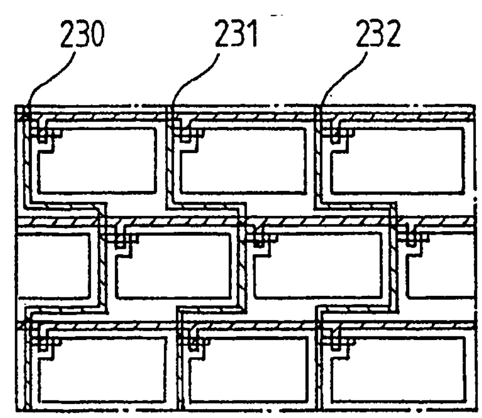
230
231
232

Fig. 23.

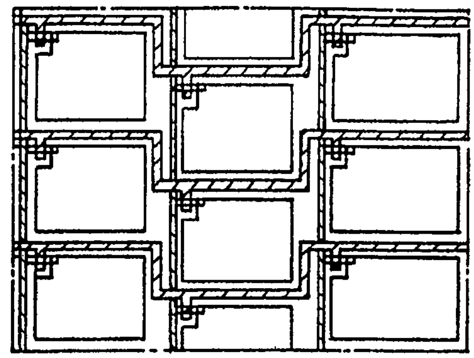

Fig. 24.

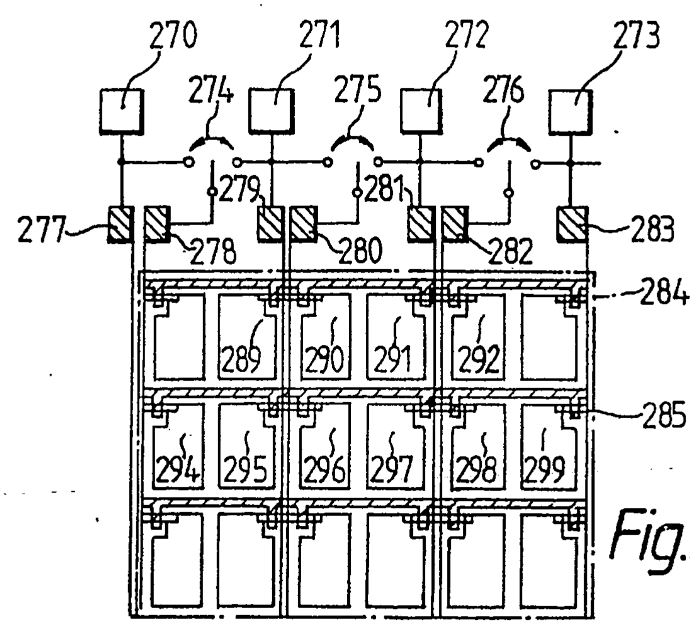


Fig. 25.

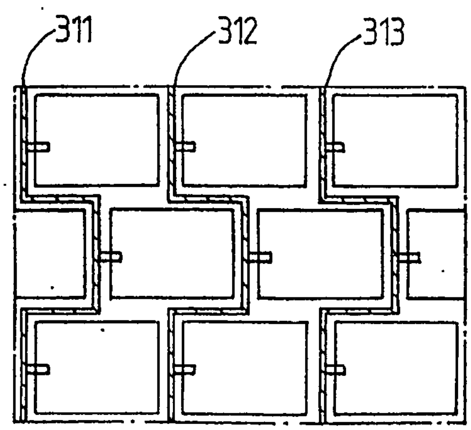


Fig. 26.

SPECIFICATION

## Liquid crystal display device

This invention relates to liquid crystal display devices.

Conventionally it has not been possible to provide a liquid crystal display device with a multi-colour display for the following reasons. Firstly, it is not possible to increase the number of dots or lines in a conventional liquid crystal display device because the conventional liquid crystal display device has at most a 1/16 duty ratio and thus only 16 lines can be driven using a conventional multiplex driving system. A liquid crystal display device which has a multi-colour display needs at least 100 lines, and thus a 1/100 duty ratio must be possible.

Secondly, it is extremely difficult to obtain a multi-colour display on a single substrate especially in the case where colouring materials are included in the liquid crystal material such as in a guest-host liquid crystal display device. To superimpose panels having different colour compositions increases cost and the resultant liquid crystal display device cannot produce a clear multi-colour display.

According to one aspect of the present invention there is provided a liquid crystal display device comprising; a pair of transparent substrates; and a matrix of picture elements arranged in rows and columns, each picture element being composed of a drive circuit, first driving electrode means on one substrate, second driving electrode means and a colour filter of one of the primary colours on the other substrate and a liquid crystal material between the electrode means, the colour filters on said other substrate being arranged in a mosaic or in strips.

Each drive circuit may include a thin film transistor or a non-linear resistive element.

Preferably each column or row of picture elements is shifted or displaced relative to each adjacent column or row.

Advantageously the area of the colour filter of each picture element is less than the area of the respective first or second driving electrode means.

The liquid crystal display device may include selecting means for selecting three primary colour video signals sequentially in synchronism by respective clock signals having the same frequency which is one-third the frequency of a selecting signal for selecting rows or columns of picture elements, and means for applying the video signal from the selecting means to the first or second driving electrodes of the picture elements.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 is a schematic cross-section of one embodiment of a liquid crystal display device according to the present invention;

Figures 2 and 3 illustrate the construction of colour filters of a liquid crystal display device according to the present invention;

Figure 4 consists of Figure 4(a) which is a plan view of an active matrix element of a liquid crystal display device according to the present invention, Figure 4(b) which is an equivalent circuit diagram of the active matrix element of Figure 4(a) and Figure 4(c) which is a section taken on the line A—B of Figure 4(a);

Figure 5 consists of Figures 5(a) which is a plan view of another active matrix element of a liquid crystal display device according to the present invention and Figure 5(b) which is a section of the active matrix element of Figure 5(a) taken on the line A—B;

Figure 6 consists of Figures 6(a) which is a plan view of a further active matrix element of a liquid display device according to the present invention and Figure 6(b) which is a section of the active matrix element of Figure 6(a) taken on the line A—B;

Figure 7 shows the voltage-current characteristics of a non-linear element;

Figure 8 is an equivalent circuit diagram to illustrate the driving of a liquid crystal display device according to the present invention having non-linear active matrix elements;

Figures 9(a), 9(b) and 9(c) show, in detail, the construction of a liquid crystal display device according to the present invention;

Figures 10, 11 and 12 are circuit diagrams of various embodiments of driving circuit for a liquid crystal display device according to the present invention;

Figure 13 is a timing chart illustrating the operation of the driving circuit of Figure 12;

Figure 14 is a block diagram of a circuit for generating clock signals for the driving circuit of Figure 12;

Figure 15 is a timing chart illustrating the operation of the circuit of Figure 14;

Figure 16 is a circuit diagram of another embodiment of a driving circuit of a liquid crystal display device according to the present invention;

Figure 17, consisting of Figures 17(a) and 17(b), shows graphically the relation between contrast of display produced by liquid crystal material and applied voltage and sample-hold operation of a video signal in a liquid crystal display device according to the present invention;

Figure 18 is a block diagram of another embodiment of a driving circuit for a liquid crystal display device according to the present invention;

Figure 19 is a timing chart illustrating the operation of the driving circuit of Figure 18;

Figure 20, consisting of Figures 20(a) and 20(b) shows the fundamental construction of high resolving power picture elements of a liquid crystal display device according to the present invention;

Figure 21 shows the construction of driving electrodes of a liquid crystal display device according to the present invention driven by a multiplex driving system;

Figure 22, consists of Figures 22(a) and 22(b) and shows part of a liquid crystal display device

according to the present invention employing thin film transistors;

Figures 23 and 24 show arrangements of liquid crystal display devices according to the present invention where electrodes are staggered;

Figure 25 shows another embodiment of a liquid crystal display device according to the present invention; and

Figure 26 shows a modification of the construction shown in Figure 20(a).

Figure 1 illustrates one embodiment of a liquid crystal display device according to the present invention. A red filter 8, a great filter 9 and a blue filter 10 are formed as a mosaic or in strips on a substrate 1. A passive layer 6, for example of silicon dioxide, is formed over the filters. A transparent electrode 5, acting as a liquid crystal driving electrode, is formed on the passive layer 6. In some instances the passive layer can be omitted. A layer 3 of active matrix elements, for example, switching elements or non-linear elements, is formed on a glass substrate 2. Transparent electrodes 4 corresponding to the active matrix elements are formed on the layer 3. Liquid crystal material 7 is encapsulated between the substrates 1, 2 in contact with the electrodes 4, 5 and the periphery of the glass substrates is sealed. In operation light passes through a polariser (not shown) and the light polarised thereby passes through the glass substrate 1. Light having fixed wavelength corresponding to a predetermined colour emerges from each of the filters 8, 9, 10 and passes through the liquid crystal material 7. If a voltage is applied to one or more of the electrodes 4 the coloured light in the region of that electrode or electrodes will pass therethrough. If no voltage is applied to one or more of the electrodes 5 light in the region of that electrode or electrodes will be blocked. Thus by selectively applying a voltage to the electrodes 4 a multi-colour display can be produced, the combination of the three primary colours red, green and blue giving the seven colours of the visible spectrum.

Various brightness levels of the colours can be achieved by using the gray scale resulting from the semi-transparent states of the liquid crystal material.

Figure 2 illustrates the construction of colour filters of a liquid crystal display device according to the present invention. A water soluble organic resin layer of, for example, polyvinyl chloride or gelatine is formed on a transparent glass substrate 20, the water soluble organic layer then being coloured with red, blue and green colouring materials by printing. The colouring materials are arranged in predetermined patterns to form red, blue and green coloured filters 22, 23, 24. A black border or frame 21 is provided by colouring the boundary of each colour filter with black pigment. This is to avoid blurring of colour at the boundary of each colour filter. However, the frame 21 is not required in the case where the resin layer is of, for example, gelatine which can be etched away. In the case of a negative type liquid crystal display device, a colour inhibitor must be included in the frame 21 in addition to the black pigment since the colouring power of the colouring materials along the lateral direction is relatively strong.

Next, a transparent passive film 25 is formed on the colour filters and a transparent conductive electrode 26 is formed on the passive film 25 and photo-etched to give the necessary pattern. The transparent conductive electrode 26 may be formed directly on to the colour filter without the passive film 25. In this case, the transparent conductive film 26 may function also as the passive film.

The colour materials of the colour filters may deteriorate or be damaged when the transparent conductive electrode is formed. This disadvantage can be avoided (as shown in Figure 3) by forming a passive layer 34 on colour filters 31 on a transparent glass substrate 30 and by forming a transparent conductive electrode 34 on a thin glass or plastics film 32 and then adhering it to the glass substrate 30.

Figure 4 shows an active matrix element 41 of a liquid crystal display device constructed on a transparent substrate. This type of active matrix element has the advantage that a driving duty ratio of more than 1/100 can be attained and a gray scale display can easily be achieved. The active matrix element of Figure 4 includes a silicon thin film transistor 49 on a transparent glass substrate of, for example, pyrex (Trade Mark) or quartz having a comparatively high melting point. Thin film transistors can be more easily constructed on a transparent glass substrate compared with forming conventional active matrix elements on a single crystal wafer of silicon.

Figure 4(a) shows the active matrix element of a picture matrix. A gate line 44 (selecting Y-line) is connected to the gate of a transistor 49, a data line 43 (X-line) is connected to the source of the transistor 49 through a contact hole 47 and a liquid crystal driving electrode 42 is connected to the drain of the transistor 49 through a contact hole 46. A capacitor 48 for maintaining electrical charge is formed between a ground line 45 and the electrode 42.

Figure 4(b) is an equivalent circuit diagram of the active matrix element 41. When the transistor 49 goes to the ON state a voltage through the data line 43 is applied to the capacitor 48 and the electrode 42. Electrical charge is thus stored by the capacitor 48 between the ground line 45 and the electrode 42. Thus electrical charge can be maintained for a long period of time since current leakage through the transistor and the liquid crystal material is negligibly small. The principal duty ratio is determined by the period of time the electric charge is maintained/the time necessary for inputting a data signal, and this value can be more than 10,000. However, the capacitor 48 is not needed as adopting large area of liquid crystal driving electrode.

Figure 4(c) is a sectional view of the active matrix element taken on the line A—B of Figure

4(a). A first thin film layer silicon channel region is formed on a transparent substrate 40 by a low pressure chemical vapour deposition technique or a plasma chemical vapour deposition technique and is then patterned. An oxidation layer is formed by oxidising the surface of the first thin film layer and after that a second thin film layer of silicon is formed. The gate line and the ground line are formed by patterning the second thin film layer. The oxidation layer is then etched using the second thin film layer as an etching mask. Thus a gate insulating film 51 and a gate electrode 50 are formed. An N-type layer is formed by implanting positive ions into the first thin film layer utilizing the gate electrode 50 as a mask. Thus, a source 53, a channel 55 and a drain 54 of the transistor 49 are formed. Next an oxidation layer 52 is deposited, a contact hole is formed and the data line 43 and electrode 42 are formed by depositing a transparent conductive film with subsequent patterning. In this construction the electrode 42 plays the role of a light shutter so that coloured light coming from the colour filter corresponding in position to the active matrix element 41 is transmitted or blocked by this shutter. Furthermore, gray scale display can be achieved by varying light transmittance of the liquid crystal material continuously by controlling the level of the voltage applied to the data line 43. A liquid crystal display device constructed of active matrix elements as shown in Figure 4 has the advantage that a full colour display can be produced by mixing the primary colours varying the intensity of each colour using the gray scale levels. Further a display composed of a 500×500 matrix of picture elements can be formed because of the extremely high duty ratio using a point or dot at-a-time system.

Additional means for improving driving duty of a liquid crystal display device according to the present invention is to use non-linear elements as part of the active matrix elements. Figures 5 and 6 show the construction of active matrix elements employing non-linear elements.

An active matrix element 61 shown in Figure 5 consists of a driving electrode 57, a MIM (metal-insulator-metal) element 62 and a X-line 58. The electrode 57 is driven by applying a data signal to it via the MIM element 62 from the X-line 58. Figure 5(b) illustrates the construction of the active matrix element of Figure 5(a). A tantalum film is formed on a substrate 56 by sputtering and is then patterned to form the X-line 58. An oxidation layer 59 300 Å to 500 Å in thickness is formed on the tantalum film by anodizing it. After that, a tantalum layer 60 is formed by sputtering and then patterned to form an upper electrode. Next the electrode 57 is formed.

An active matrix element 64 shown in Figure 6 has two diodes connected in series. An X-line 66 is connected to an electrode 65 through a N- or P-type area 67, a P- or N-type area 68 and an N- or P-type area 69. Figure 6(b) illustrates the construction of the active matrix element of Figure 6(a). After foming an island of silicon in a transparent substrate 61, the N- or P-type areas 67, 69 and the P- or N-type area 68 are formed by ion implantation. A transparent conductive film is then formed and the X-line 66 and the electrode 65 are formed.

A non-linear element has characteristics as shown in Figure 7, current sharply increasing when the voltage is at a given level.

The equivalent circuit shown in Figure 8 illustrates driving of a picture element consisting of a liquid crystal cell 81 and a non-linear element 80. The non-linear element 80 is shown as a non-linear resistance RM and a capacitor CM and the liquid crystal cell 81 is shown as an equivalent resistance RL and a capacitor CL.

An operating voltage VD higher than the threshold level is applied to the non-linear element 80 when the liquid crystal cell 81 is to produce a display, a voltage VM almost equal to an applied voltage VD being applied to the liquid crystal cell because of the low resistance of the resistor RM. Thus, in effect, a voltage VM almost equal to the voltage VD is applied to the liquid crystal cell. The resistance RM becomes extremely high as the operating voltage VD falls below the threshold level. The voltage VM gradually decreases due to discharge of the capacitor CL, the time constant of the discharge being determined by the resistance of the resistor RL and the capacitance of the capacitor CL but the voltage causing the liquid crystal cell to produce a display can be maintained for a relatively long time. While the liquid cell is not producing a display, the voltage VM is nearly 0 volts. Therefore, the voltage VM for causing the liquid crystal cell to produce a display is held on the capacitor CL so that the duty ratio of the liquid crystal display device as a whole can be increased. This is a similar effect to that achieved by the active matrix element shown in Figure 4. The electrodes 57, 65 of the active matrix elements of Figures 5 and 6 also play the role of a light shutter.

The advantage of using non-linear elements in active matrix elements of a liquid crystal display device according to the present invention is their simple construction enabling conventional simple multiplex driving systems whose duty ratio is either 1/8 or 1/16 to be employed. Non-linear elements can be used to produce gray scale display. There are two ways of driving a liquid crystal display device to produce a gray scale display. One method is to drive active matrix elements such as shown in Figure 4 with voltages corresponding to the contrast level or gray scale thus producing a continuous gray scale display. The voltages corresponding to the gray scale display can be obtained by sampling and holding an image signal, that is, a dot at-a-time system. Another method of driving a liquid crystal display device to produce a gray scale display is to drive the active matrix elements by varying the pulse width of a driving signal. For instance sixteen levels of the gray scale display can be obtained by dividing a selecting frame into 16 terms wherein

one term means one level of the gray scale display. The above-mentioned pulse width modulation system is a line at-a-time system.

In the case of driving liquid crystal display devices with active matrix elements including non-linear elements both a line at-a-time driving system and a dot at-a-time driving system can be used.

In the embodiments according to the present invention described so far the colour filters are formed on one substrate and the active matrix elements on the other substrate with the liquid crystal material therebetween. If the active matrix elements are formed directly on the colour filters the characteristics of the colour filters may deteriorate and there is a tendency to decrease manufacturing yield. There are two ways of avoiding such problems. One way is form the active matrix elements on a thin film (such as the film 32 shown in Figure 3) and then attach it to the colour filters. Another way is to form the active matrix elements on a substrate first and then form the colour filters on the active matrix elements.

Figure 9 shows in detail an embodiment of a liquid crystal display device according to the present invention. Figure 9(a) shows a glass substrate 99 with active matrix elements 90 thereon and respective driving electrodes 97. Red (R), blue (B) and green (G) colour filters 92, 93, 94 are formed on a glass substrate 91. A passive layer 95 covers the colour filters and a driving electrode 96 is formed thereon. A liquid crystal layer 98 is disposed between the glass substrates 90, 91. A polarizing plate (not shown) is attached to either glass substrate and light is applied through the polarizer into the liquid crystal display device.

There is a problem of light shielding because of the existence of gaps between the colour filters or between the electrodes 97, light entering these gaps causing deterioration of the colour display. For instance, when light is passed through the glass substrate 91 some light leaks through the gaps between the colour filters and between the electrodes 97 even if the active matrix elements are not energised.

There are two possible measures to counter this problem. One measure is to use negative-type liquid crystal material where light is not transmitted without a voltage being applied. Thus the transmittence of light is always shielded through the gaps between the electrodes 97. Another measure is to form a black frame between the colour filters as shown in Figure 2. The use of these two measures together brings about an even more effective result.

The appearance of light passing through the liquid crystal material may be blurred upon energising the active matrix elements. For example when only the active matrix elements above the filter 92 is energised some light at the edges adjacent the filter 94 and the filter 93 may leak through the active matrix element corresponding to the filter 92. This light leakage causes the colour display to deteriorate. To avoid this problem the colour filters should have a large area compared to that of the corresponding active matrix elements. For example, the driving electrodes 97 of the active matrix elements are made smaller than the corresponding colour filters as shown in Figure 9(b) and Figure 9(c).

Liquid crystal display devices which produce a multi-colour display require that the difference in the transmission of light between an opened state of liquid crystal shutter and closed state must be relatively large. When the liquid crystal display device is of the normal positive twisted nematic type two polarizers are used, one being disposed on each side of the liquid crystal display device. In this case the light transmittance ratio is determined by the arrangement of polarizers, the ratio being taken in directions parallel and vertical to the polarisers. Practically this ratio is from 10 to 50.

In the case of a guest-host liquid crystal display device, the brightness is twice that of a twisted nematic liquid crystal display device and the transmittance ratio, which is relatively large, is solely determined by the liquid crystal material since only one polarizer is needed. For instance, in most cases a guest-host liquid crystal display device includes a black colouring material which completely blocks light until a voltage is applied when it becomes transparent so that the light transmittance is over 50.

Moreover, a positive-type guest-host liquid crystal display device shows excellent characteristics compared with the negative-type, especially stability, reliability, lower driving voltage and large transmittance ratio. Further positive-type guest-host liquid crystal display devices are advantageous from the point of view of avoiding leakage and blurring of light. Thus ideally a liquid crystal display device according to the present invention is of the guest-host type and black colouring material in the liquid crystal material enables an excellent multi-colour display to be produced using three primary colours.

Figure 10 is a circuit diagram of a driving circuit for a liquid crystal display device according to the present invention using a point or dot at-a-time system. Filters 106 of three primary colours are arranged in strips in the Y-direction and driving electrodes adjacent the filters are arranged either as strips extending in the same direction as the filters or all over the filters. Upper electrodes 105 are arranged in strips in the X-direction. Thus a matrix of picture elements is formed. A shift register 101 supplies signals $S_1 \ldots S_n$ to respective transistors 104 in synchronism with a clock signal $\phi_5$, and a video signal VS from an amplifier 103 is supplied to the electrodes $X_1$ to $X_n$ successively by rendering the transistors 104 conductive in a point or dot at-a-time system. A shift register 102 selects Y-lines $Y_1 \ldots Y_m$ successively in synchronism with a clock signal $\phi_4$. Three colour signals VSR, VSB, VSG are selected for every Y line in synchronism with clock signals $\phi_1$, $\phi_2$, $\phi_3$. The clock signals $\phi_1$, $\phi_2$, $\phi_3$

have the same pulse width as the clock signal $\phi_4$ but a period which is three times as long as that of the clock signal $\phi_4$. In this method, the filters are arranged as strips in the Y direction and the frequency for changing over the colour signals can be delayed. Thus the number of lines in the Y direction can be increased so that a superior resolving power can be obtained and a good quality display can be produced.

Figure 11 illustrates another embodiment of a driving circuit for a liquid crystal display device according to the present invention where colour filters 116 are arranged in strips extending in the X direction and using the same point or dot at-a-time system as Figure 10. Therefore the number of lines in the transverse direction can be increased and the picture elements are in the form of square dots. Thus a natural display can be produced. In Figure 10, the output from a shift register 112 selects driving electrodes 115 successively in synchronism producing signals for Y lines $Y_1$ to $Y_m$. While one of the driving electrodes 115 is selected, a shift register 111 selects successively a unit group consisting of red, green and blue (R, G, B) filters. In addition clock signals $\phi_1$, $\phi_2$, or $\phi_3$ produced by dividing a clock signal $\phi_5$ into three phases select successively in synchronism colour video signals VSR, VSG, VSB which are transmitted to the X lines. In this method, the video signal lines are in parallel with each other according to every colour video signal and connected to sample hold switches 113. This is advantageous from the point of view of reduction of power consumption of the shift register 111 which can be used within the range of its operating speed, since the frequency of the clock signal $\phi_5$ can be one-third of the number of dots.

Figure 12 illustrates a further embodiment of a driving circuit for a liquid crystal display device according to the present invention where the colours R, G, B of the colour filters are arranged in a mosaic. A colour R, G, B is allocated to each picture element, the colours being shifted by one pitch to the left in each X line. For example, each picture element shown in Figure 12 is driven by signals from X- and Y-lines constructed on the glass plate as shown in Figures 4 to 8. A shift register 122 receives a clock signal YCL and selects gate or Y lines $Y_1$ to $Y_m$ successively in synchronism. On the other hand, during the period of selecting one of the Y lines, a shift register 121 supplies signals $S_1$ to $S_n$ successively to the gate of transistors 123 for data or X-lines $X_1$ to $X_n$. A video signal Vs from an amplifier 124 is sampled successively by the transistor 123 and held on the X-lines $X_1$ to $X_n$ by actuating the gates of transistors 123. Thereby, the video signal is transmitted to respective picture elements and a display can be produced. The video signal Vs consists of respective colour signals VSR, VSB, VSG multiplexed in synchronism with clock signals $\phi_1$, to $\phi_3$. It is necessary that the timing of the clock signals $\phi_1$ to $\phi_3$ corresponds to the arrangement of each colour filter allocated to the picture element. For example during the period of selecting the Y-line $Y_1$, the signal $S_1$ must be applied to the gate of the transistor in synchronism with the clock signal $\phi_1$, but during the period of selecting the Y-line $Y_2$, this signal must be applied to the gate of the transistor in synchronism with the clock signal $\phi_2$ because the video signal VSR must be supplied to the picture element with the colour R and the video signal VSG must be supplied to the picture element with the colour G.

Figure 13 is a timing chart illustrating the operation of the driving circuit of Figure 12. In the case of selecting the Y-line $Y_1$, firstly the video signal VSR is supplied to the X-line $X_1$ in synchronism with the clock signal $\phi_1$ whilst the signal $S_1$ is applied to the gate of the transistor 123 of the X-line $X_1$. The video signal VSG is applied to the X-line $X_2$ in synchronism with the clock signal $\phi_2$ whilst the signal $S_2$ is applied. The video signal VSB is supplied to the X-line $X_3$ whilst the signal $S_3$ is applied.

While in the case of selecting the Y-line $Y_2$, firstly the video signal VSG, secondly the video signal VSB and thirdly the video signal VSR are supplied to the X-lines $X_1$, $X_2$, $X_3$ respectively in dependence upon the signal $S_1$, $S_2$, $S_3$ applied to the gates of the transistors 123 for the X-lines $X_1$, $X_2$, $X_3$. Thus it is necessary to shift the clock signals $\phi_1$, $\phi_2$, $\phi_3$ for each of the Y-lines in order to supply the requisite video signals VSG, VSB, VSR to the respective colour filters.

The circuit shown in Figure 14 is an example of a circuit for shifting the phases of the clock signals $\phi_1$ to $\phi_3$, its operation being illustrated by the waveforms of Figure 15. A 1/3 frequency divider 143 is reset by a vertical synchronising signal V to supply signals $Q_1$, $Q_2$ to a 1/3 frequency divider 142 in synchronism with a Y clock signal YCL. The 1/3 frequency divider 142 divides the signals $Q_1$, $Q_2$ by 1/3 in synchronism with a X clock signal XCL and loads or presets the values of the signals $Q_1$, $Q_2$ every time a horizontal synchronizing signal H is inputted. Therefore the phases of signals $Q_3$, $Q_4$ from the 1/3 divider are shifted every pulse of the clock signal YCL and the respective video signals can be properly applied to the respective picture elements in the driving circuit shown in Figure 12.

Figure 16 is another embodiment of a driving circuit of a liquid crystal display device according to the present invention. A red filter 161, a green filter 162, a blue filter 163 and a white filter 164 are formed in a block and a plurality of such blocks are arranged in a matrix. In the case of low level transmission of light through the colour filters, it is a problem to get good reproduction of a white colour. In order to solve this problem, this embodiment provides a transparent portion as the white filter 164 this being controlled by an luminance video signal VSW. Thus the whole brightness can be improved and white colour produced fairly well. In this driving circuit with respect to the X direction a shift register (not shown) controls picture elements in the same

manner as Figure 11. In addition, with respect to the Y direction, the Y-line $Yi$ or the Y-line $Yi+1$ is selected in synchronism with a clock signal $\phi_3$ and video signals VSR and VSB or video signals VSG and VSW are alternately supplied to the corresponding filters in synchronism with the clock signals $\phi_1$, $\phi_2$, the frequency of which is one-half that of the clock signal $\phi_3$.

Figure 17 shows how to control voltage amplitude to produce gray scale display. A video signal VS shown in Figure 17(a) is sampled and held in synchronism with a clock signal $\phi_5$ and supplied to an X-line. The characteristic curve of applied voltage V relative to contrast C is as shown in Figure 17(b). A gray scale display can be produced with the voltage in the range of $\Delta V$. A more superior gray scale can be achieved by implementing $\gamma$ correction or video signal correction according to the characteristics of the liquid crystal material.

The above-mentioned means of producing a gray scale display by controlling voltage amplitude is mainly adopted to drive a liquid crystal display device with active matrix elements composed of thin film transistors or non-linear elements while the production of a gray scale display by controlling or modulating pulse width is mainly adopted for a liquid crystal display device of high duty multiplex construction or composed of non-linear elements.

Figure 18 illustrates another embodiment of a driving circuit of a liquid crystal display device according to the present invention which is driven by a pulse width modulation system. The colour filters 146 are arranged in a mosaic. For example, in a high duty ratio multiplex driving system, driving electrodes are arranged in a similar manner to that shown in Figure 9(c), namely the X-lines on a lower glass substrate and Y-lines on an upper glass substrate, the colour filters being deposited on either the X-lines or the Y-lines. Colour video signals VSR, VSG, VSB are multiplexed in synchronism with the clock signals $\phi_1$ to $\phi_3$ in the same manner as described with reference to Figure 12, and are outputted to a 4-bit A/D converter 187. Outputs $D_0$ to $D_3$ from the converter 187 are transmitted to a shift register 180 during the period of selecting the Y-lines Y and supplied to a latch 181 in synchronism with a pulse LP. A 4-channel multiplexer 182 forms pulses having different pulse width, where a 4-bit data signal selects one of time bases TB0 to TB3. These pulses are supplied to X-lines $X_1$ to $X_n$ *via* a driver 183.

The Y-lines are selected successively by a shift register 184, and a driver 185 supplies the selecting signal to the Y-lines.

Figure 19 illustrates the operation of the driving circuit of Figure 18. A frame has a positive field A and a negative field B, and the width of a driving pulse $Xi$ is selected within one selection period T SEL. For instance, in the case where the gray scale is 0, the driving waveform is shown as $Xi(0)$, in the case where the gray scale is 7, the driving waveform is shown as $Xi(7)$, and in the case where the gray scale is 15 the driving waveform is shown as $Xi(15)$. These driving waveforms are formed by combining time bases TB0 to TB3 as indicated by the 4-bit data signal. In the high duty multiplex driving system or the matrix driving system utilising non-linear elements, the Y-lines are formed by dividing the driving electrodes into respective lines.

On the other hand, in the matrix driving system utilising thin film transistors, a Y-line is formed on the same substrate as the X-line and a transparent driving electrode film of, for example, indium-tin-oxide or other transparent conductive film is deposited all over the surface of the opposite substrate.

Thus in the liquid crystal display device shown in Figure 9, the transparent driving electrode film completely covers all the colour filters. Accordingly, this construction removes the problem that the colour filters and the liquid crystal material react with each other to reduce reliability since the transparent driving electrode film shields completely the colour filters from the liquid crystal material. Thus the transparent driving electrode film acts as a passive film in this context and this is particularly advantageous.

In a practical liquid crystal display device, sometimes there is a problem with resolving power. Arranging the colour filters in a mosaic improves the resolving power as will be explained.

Figure 20 shows the fundamental construction of high resolving power of liquid crystal display devices according to the present invention. Figure 20(a) shows colour filters shifted by 1/2 pitch in the X direction and Figure 20(b) shows colour filters shifted by 1/2 pitch in the Y direction. The resolving power of the abovementioned arrangements of picture elements is increased in the oblique direction. Therefore oblique lines are not visible and resolving power can be considerably increased. The colour filters R, G, B are each arranged at the apex of a triangle consisting of colour filters R, G, B. Thus proper resolving power can be obtained even where fewer picture elements are used.

Figure 21 illustrates driving electrodes of a liquid crystal display device driven by a multiplex driving system. X electrodes are arranged and shifted by 1/2 pitch with distributing wires in similar manner to that shown in Figure 20(a). The X and Y electrodes are normally transparent conductive electrodes, the distributing wires being of very small width and made from a deposited metallic thin film so as to lower electrical resistance.

Figure 22 shows part of a liquid crystal display device according to the present invention employing thin film transistors to improve resolving power. The liquid crystal display device has data lines 213 to 215 and gate lines 210 to 212. The transistors and the picture element electrodes are normally arranged in odd-number gates lines as shown by a transistor 216 and a driving electrode 217. On the other hand, for even-numbered gate lines, transistors 219, 22

and driving electrodes 221, 223 are arranged in parallel with each other relative to data line 214, namely are substantially shifted by 1/2 pitch. Figure 22(a) shows the case where the data lines 213 to 215 and the driving electrodes 217, 220, 221, 223 are formed in or on the same layer. In the case where the data lines and the driving electrodes overlap, it is also possible to shift a driving electrode 224 itself by 1/2 pitch with a single transistor 225 as shown in Figure 22(b).

Figure 23 shows another embodiment of a liquid crystal display device according to the present invention employing thin film transistors. Data lines 230 to 232 are shifted by 1/2 pitch by making them zig-zag. It is advantageous that unnaturalness caused by shifting electrodes by 1/2 pitch can be removed, since the size of picture elements is quite the same in both shifted portion and unshifted portion.

Figure 24 shows a similar arrangement where the driving electrodes are shifted by 1/2 pitch in the Y direction by making the gate lines zig-zag.

Figure 25 shows a yet further embodiment of a liquid crystal display device according to the present invention using thin film transistors. Drivers 270 to 273 are directly connected to data lines 277, 279, 281, 283. Data lines 278, 280, 282 are alternately connected to right or left drivers every scanning of one gate line. For example, when a thin film transistor is turned ON by a gate line 284 and switches 274 to 276 are set to the left position, the same data is supplied to both picture elements 289, 290 and picture elements 291, 292 as pairs, respectively. Then, when the thin film transistor is turned OFF by the gate line 284 and is turned ON by a gate line 285, and the switches 274 to 276 are set to the right position, the same data is respectively supplied to three pairs of picture elements 294, 295, 296, 297, and 298, 299. Thus the method shown in Figure 20(a) can be realised.

Figure 26 shows a modification of the construction of Figure 20(c) wherein the data lines or X-lines 311, 312, 313 are staggered.

The liquid crystal display devices according to the present invention and described above produce a coloured display and use a large volume driving system such as a high duty ratio system, a multiplex driving system or a driving system where thin film devices, such as non-linear elements or thin film transistors are used. Light transmission type liquid crystal display devices can be constructed where some increased power consumption is allowable and light reflection liquid crystal display devices can be constructed where the plane of reflection is deposited on the lower side can be utilised for low power consumption. In one embodiment of the present invention a full colour display composed of more than 100×100 lines was achieved with excellent image quality without distortion, compart size display and low power consumption for producing graphical picture displays of quality comparable to that of cathode ray tubes.

The embodiments of the present invention and described above employ three different systems for enlarging the duty ratio. Firstly, in the multiplex driving system superhigh duty ratio from 1/60 to 1/200 can be realised by improving the liquid crystal material and using sophisticated construction techniques for the liquid crystal display device. Secondly, the gap between the electrodes of the liquid crystal display device must be controlled to be from 5 $\mu m$ to 7 $\mu m$ instead of the conventional 10 $\mu m$. Thirdly, active matrix elements, such as transistor switches, non-linear elements (MIM elements or diodes) are used in the driving circuit. One embodiment of a liquid crystal display device according to the present invention uses negative type liquid crystal micro-shutters which open and close colour filter dots which are arranged in a mosaic or in strips in order to product a colour display. It has been found that fine and clear colour displays can be realised in such embodiments.

Claims

1. A liquid crystal display device comprising: a pair of transparent substrates; and a matrix of picture elements arranged in rows and columns, each picture element being composed of a drive circuit, first driving electrode means on one substrate, second driving means and a colour filter of one of the primary colours on the other substrate and liquid crystal material between the electrode means, the colour filters on said other substrate being arranged in a mosaic or strips.

2. A liquid crystal display device as claimed in claim 1 in which each drive circuit includes a thin film transistor or a non-linear resistive element.

3. A liquid crystal display device as claimed in claim 1 in which each column or row of picture elements is shifted or displaced relative to each adjacent column or row.

4. A liquid crystal display device as claimed in any preceding claim in which the area of the colour filter of each picture element is less than the area of the respective first or second driving electrode means.

5. A liquid crystal display device as claimed in any preceding claim including selecting means for selecting three primary colour video signals sequentially in synchronism by respective clock signals having the same frequency which is one-third the frequency of a selecting signal for selecting rows or columns of picture elements, and means for applying the video signal from the selecting means to the first or second driving electrodes of the picture elements.

6. A liquid crystal display device substantially as herein described with reference to and as shown in the accompanying drawings.

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